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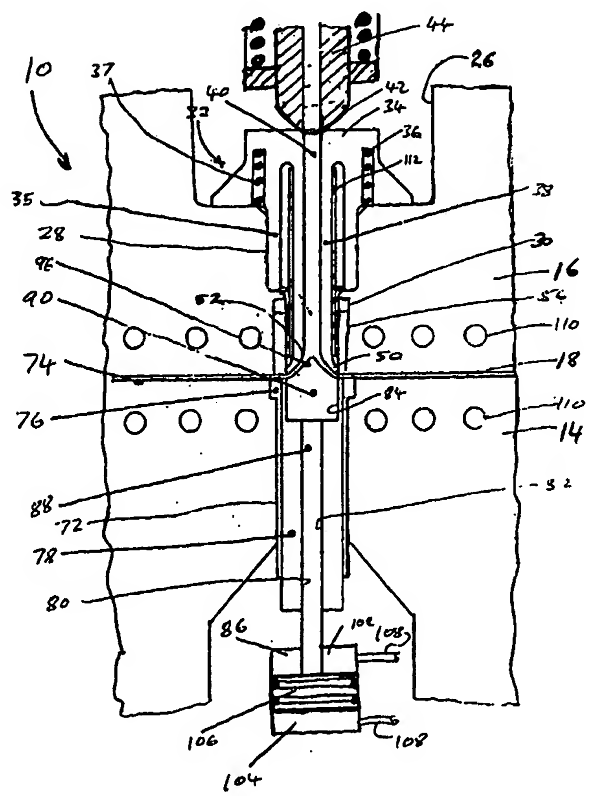
(57) Abstract

An injection molding apparatus and method provides a mold injection nozzle (32) slidably mounted in a bore (28, 30) extending through a first mold half (16) and, optionally, a back plate. The mold nozzle (32) has a tip portion (50) providing a tip surface. In a second mold half (14), there is a corresponding, aligned bore, in which is located a plug (90). The plug (90) can be displaced by a plunger (88) but is separate from the plunger (88). In use, the plug (90) can be used to control the width of a gate between the plug (90) and the tip surface through which resin flows into the cavity. After molding, the plug (90) is displaced from its bore (72) into the bore (30) in the other mold half (16), both to close off the tip portion and to displace the plug (90) and tip portion away from the mold cavity (18). The mold is then opened with the plug (90) and the mold injection nozzle (32) being retained in the first mold half (16).



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APPARATUS FOR AND METHOD OF INJECTION MOLDING

FIELD OF THE INVENTION

This invention relates to an apparatus for and a method of injection molding articles from plastic, and more particularly is concerned with the molding of high quality articles requiring an accurate hole or aperture through the article, without any weld lines. This invention is more particularly intended for use in molding generally circular articles such as optical or magnetic discs, or precision gears.

BACKGROUND OF THE INVENTION

The molding of objects with apertures or holes, for example, gears, wheels, etc. with a central hole, has always presented problems. Often, such a part is molded by injecting plastic from at least one side of a mold cavity. This will often result in weld lines being formed of plastic material, as when the molten plastic flows through the cavity and around the metallic core that forms a hole or aperture in the object. For many purposes, this can be tolerated, and by appropriate selection of injection conditions, the effect of weld lines can be minimized and accepted.

More recently, there are new classes of articles, for which much higher tolerances and uniformity are required. In particular, there is a growing demand for optical discs. These have a disc substrate formed from a synthetic resin, such as a light-transmitting polycarbonate resin. A read only disc has a spiral track with a series of recesses and lands encoding desired information, which can be a musical sound signal, an optical image, or digital information. A reflective film, produced for example, by vacuum deposition of aluminum is provided. The information is read by reflection of a laser beam from the recesses and lands. This requires the disc not only to have uniform mechanical properties but also to have extremely uniform optical properties. In current discs for recording musical sound and the like, known as compact discs or CDs, the pits have a certain size. More recently, it has been proposed to use the same technique for digitally encoding video signals, with pits having a much smaller dimension to enable more information to be encoded, and such

discs are known as Digital Versatile (Video) Discs (DVDs), which may be double sided. With such small dimensions, it is essential to have consistent and uniform optical characteristics.

More particularly, any variation in the refractive index is wholly unacceptable. This can result from material used to manufacture any individual disc having a wide variety of shear history throughout. Also, weld lines can cause birefringence problems, which again are unacceptable. Similar considerations apply to a magneto-optical disc, capable of rewriting information signals.

This problem has been recognized, at least for recording discs of the type described above. A common feature of proposals for molding such discs is to inject the plastic through a nozzle located on the axis of the disc. Plastic first flows axially and then turns 90° at a gate to flow radially outwardly. The intention is that the plastic will fill the cavity uniformly, avoid weld lines, and avoid complex and non-uniform shear history in the material. However, these characteristics have not always been obtained to date, and often other problems are generated.

RELATED ART

The disclosures of all references mentioned in this description are incorporated herein by reference.

US Patent 2,698,464 issued to Wilson describes a double cavity mold to form record discs having a central hole. This design shows a freely moving pin element that has two functions: it seals the machine injection nozzle and it creates the hole during its back move towards the machine nozzle. This pin element of Wilson '464 does not act as a mold core, does not act as a mold gate and does not guide or direct the flow of the molten resin radially or in any other manner towards the cavity. As a major drawback, the movement of the pin element backward after injection will redirect the injected material from the mold main channel back into the already filled mold cavities and also back into the machine nozzle. This approach is unacceptable when molding information carrier discs as the extra material will create weld lines with the initially filled material. Also the

mold injection nozzle of Wilson '464 is stationary and does not have a tip portion with a gating portion to form a circular gate of a certain thickness in cooperation with the movable pin. The sealing function of the pin element of Wilson '464 can be implemented by using a lateral sliding valve gate while the hole creation function can be performed by the plunger 26.

A further hot bushing technique is taught in U.S. Patent 5,324,190 (Frei) assigned to GPT Axxicon B.V. This provides a movable valve gating element having several functions: to split the incoming flow of molten resin into several streams, to maintain the molten resin hot, to form the mold gate of a fixed thickness, to shut-off the gate and to form the hole in the molded article. Frei's design inherently introduces unacceptable weld lines by splitting the melt around the valve gate element and by delivering the melt into the cavity through several radial gates.

One proposal can be found in U.S. Patent 3,989,436 (McNeely et al.) of which the assignee of the present invention is a joint assignee. This discloses an apparatus for producing injection molded and centrally apertured recording discs, more particularly optical discs. The method disclosed is generally known as a cold bushing injection molding method. This provides a sprue bushing with a conical opening. An injection nozzle opens into one, small end of the bushing, and a wider end of the bushing opens into the disc cavity. As a cold bushing is used, plastic in the sprue bushing cools and solidifies, similarly to the plastic in the mold cavity. Immediately after the plastic is cooled, but before it has cooled down to ambient temperature and is very rigid, a central, circular portion of the disc is cut away, together with the sprue. This is then pushed out by a mechanical puncher and removed by a robot tool.

While this method provides high quality optical discs with almost no birefringence, it has some significant drawbacks. Firstly, the sprue represents a waste of expensive plastic material. Secondly, the overall cycle time is increased due to additional time required to cut and then to remove the sprue. Thirdly, some tension or stress can be created in the material immediately adjacent the hole during cutting of the sprue. In

most instances the quality of the surface of the hole and its dimensional tolerances vary and do not meet acceptance criteria. Finally, the equipment is complicated and expensive since there is the additional requirement for a robot designed to extract and remove the sprue.

A very recent development that uses a cold sprue method is disclosed in the U.S. Patent 5,552,098 of Kudo et al. assigned to Sony Corporation. The description suggests that the movable member is first withdrawn from the position forming the through hole in the disc, the disc substrate is cured within the mold, and the substrate is then removed from the mold cavity. The manner in which the mold can be opened and the disc removed is somewhat unclear, while the cold sprue is removed separately in an undisclosed manner.

An alternative approach is disclosed in U.S. Patent 4,340,353 (Mayer) assigned to Discovision Associates. Here, a second general method known as a hot bushing injection molding method is described. In this method, a bushing immediately adjacent the central aperture of a disc is maintained heated, so that the plastic in this bushing is at all times molten. This avoids formation of a sprue when plastic in the cavity cools. Closing off the cavity from the still molten plastic is achieved in U.S. Patent 4,340,353 by means of a spring-biased poppet valve. A hydraulic ram is provided for urging this poppet valve into a closed position, in addition to a compression spring. When plastic is injected into the mold, the hydraulic ram is displaced away, and the injection pressure is sufficient to displace the poppet valve from its seat against the spring action. The poppet valve provides a short, frusto-conical seat. The dimensions are such as to provide a fairly abrupt change in flow cross-section from channels of the nozzle assembly past the poppet valve seat into the cavity. With the filling process complete, the poppet valve is closed by means of a hydraulic ram, assisting the compression spring. Thus, in closing the valve, the head of the poppet valve effectively travels through just the opening in the disc and seats on its valve seat so as to be immediately adjacent the disc and the hole in the disc.

There are various problems in this arrangement. Firstly, the closed valve is immediately adjacent the inner edge of the disc, so that there is a conflicting requirement to maintain the nozzle tip and plastic within it in a molten state, while enabling the disc immediately adjacent it to cool and solidify. More importantly, the main problem with this type of valve assembly relates to obstructions in the path of the flowing molten resin that create a complex shear history pattern. This patent shows a complex flow path for the resin, so the different portions of the resin would be subject to quite different shear effects. A particular problem with the provision of a poppet valve is that necessarily an actuating shaft of a poppet must pass through the channel along which the plastic flows. As this patent shows, this results in a complex design for the poppet shaft. This includes outwardly extending arms to guide the shaft, further arms defining axial openings, separate elements bolted together, and a heater. All of this creates a complex flow path generating a complex shear history for the material, which will cause undesirable shear heating and viscous dissipation. This creates a birefringence pattern, observable with polarized light. Such a pattern is wholly unacceptable, as it disturbs the reading accuracy of the disc.

A further U.S. Patent 4,391,579 (Morrison) also assigned to Discovision Associates discloses a hot sprue valve assembly for an injection molding machine. Here a movable valve member moves between an advanced position for molding a disc and a retracted position in which resin flow is shut off and an aperture is formed. However the valve member includes a rather complex flow path. Necessarily, it includes spacer flights around which the resin must flow. This will result in separate flows combining just before entry into the mold and will result in formation of weld lines and birefringence.

Another U.S. Patent 4,412,805 (Morrison) assigned to Discovision Associates, teaches the provision of two hot sprue assemblies that do not comprise movable valve members. In both embodiments a stationary sprue bushing cooperates with a stationary die plug secured to the second

mold half to form the central hole in the molded article. Taking into account that no means are used to shut-off the gate after injecting the resin, the holes will leave residual sprues that are not acceptable. More than that, in both embodiments weld lines will appear in the molded article as a result of splitting the molten resin into several streams by mechanical obstacles and then recombining the flows. In the first embodiment of Fig. 1, there are spacer flights that divide injected molten resin into separate radial channels formed between a dispersion head and a mounting block. In the second embodiment of Fig. 5, the mechanical obstacles are the divisions between a large number of extrusion passages.

Another attempt to inject plastic articles with a central hole using a hot sprue and no movable valve members is disclosed in the US Patent 5,219,593 (Schmidt et al.) assigned to the assignee of the current invention. In the embodiment of Fig. 7, Schmidt teaches an inner plug that has a tapered end portion that fits into a corresponding tapered bore located in an opposed mold half to form a hole with no residual sprue. This method uses thermal gating to shut-off the gate, but it is still not acceptable for some applications, taking into account that the molded article will inherently show weld lines caused by splitting the flow of resin into several streams around the nozzle body. This design will also generate a visible circular residual sprue caused by the width of the gate which remains open after injection and cooling of the resin.

The assignee of the present invention, in U.S. patent application Serial Number 08/690,411 filed July 25, 1996 (Teng) discloses an improved hot bushing valve gate and method of eliminating unidirectional molecular orientation and weld lines from solidified resin used for forming molded articles. A novel design for a valve stem is disclosed that has different areas and zones intended to split, homogenize and mix the molten resin. The valve stem slides to form the hole and acts as a gate closure. While this technique has numerous advantages over the previous hot bushing methods, it still requires the presence of a movable valve stem extending through the channel of the mold injection nozzle.

Finally, there is a brochure published recently by Altech that roughly shows a CD mold design where the melt flow is tubular and reaches the cavity space with no mechanical obstructions. The schematic does not provide any information regarding the gate area, the mold nozzle and the injection sequence.

Accordingly, it is desirable to mold parts with through holes, particularly circular parts such as discs and gears, and even more particularly, information carrier molded substrates such as magnetic hard discs, writable and non-writable digital compact discs (CDs) and digital versatile (video) discs (DVDs), in a manner which avoids the disadvantages of the known techniques.

SUMMARY OF THE INVENTION

In one aspect the present invention provides an improved injection molding apparatus for forming articles including an aperture therethrough, the apparatus including a first mold half having a first bore; a second mold half having a second bore substantially aligned with the first bore, wherein the first mold half and the second mold half form a mold cavity space in the mold closed position, said mold cavity space having a thickness T1 adjacent said first bore, the improvement comprising a slidable mold injection nozzle located inside said first bore having a molding position and a post molding position, said nozzle including an inlet in fluid communication with a molten material supply means; an outlet including a nozzle tip, said nozzle tip having a gating portion and being in communication with said mold cavity space when the nozzle is in said molding position; and an unobstructed nozzle melt channel between said inlet and said outlet to guide the flowing molten material from the supply means towards the mold cavity space in tubular flow up to the outlet; independently movable sliding valve gating means located in said second bore and having a molding position therein and a post molding sealing position in said first bore, said valve gating means including mold core means to form a hole in the article to be molded, means for converting the flow of molten material from tubular to radial in the mold closed position,

and nozzle channel sealing means to prevent leakage of molten material in the mold opened position; a circular mold gate of a adaptable thickness T2, said mold gate being formed in the mold closed position between the gating portion of the nozzle tip and said valve gating means, said mold gate having no mechanical obstructions, whereby the maximum thickness T2 of said gate is substantially equal to the thickness T1 of the mold cavity space; first motive means to slide the mold injection nozzle inside the first bore between said molding and said post molding positions; and second motive means to slide the valve gating means at least partially from said molding position inside the second bore to said post molding sealing position inside the first bore.

In a narrower form, the present invention provides an injection nozzle valve gating apparatus, for use in injection molding equipment including first and second separable mold halves which together define a mold cavity for molding an article including a hole, which first and second mold halves include respective first and second guide bores opening into the mold cavity and aligned with one another, the injection nozzle valve gating apparatus comprising:

a mold injection nozzle slidably mountable in the first bore and defining a nozzle channel for supplying a homogenous flow of resin which nozzle channel has a nozzle inlet for connection to a machine injection nozzle and a nozzle outlet adjacent the mold cavity, wherein the nozzle outlet includes a tip portion and is mountable for sliding movement in the first bore between a molding in which tip portion is adjacent the mold cavity and a second position in which the tip portion is spaced away from mold cavity;

an independent shuttling plug slidably mountable in the second bore facing the nozzle outlet, wherein the tip portion and the shuttling plug include first surfaces which face one another to form a mold gate; and

displacement means for displacing the shuttling plug relative to the

tip portion for varying the spacing between the first surfaces to vary the width of the mold gate, said displacement means being mountable in the second mold half and being separate from the shuttling plug.

In more general terms, the present invention provides an injection molding apparatus and method that is capable of providing molded parts that are free from weld lines, that show minimum birefringence and that have accurate through holes. Unlike the known cold sprue methods, the current invention provides a hot sprue method and apparatus that produce quality molded parts having accurate holes, without forming any residual plastic sprue.

Further, the technique provides an adjustable mold gate the thickness and position of which in the mold cavity space are adjustable functions in accordance with the molding conditions and material to be molded, while enabling the flow rate to be controlled. For this purpose, the width of the gate can be adjusted before the injection process begins to allow formation of different articles in the same mold, even when using different resins; different injection molding machines; and/or different injection cycling parameters. The method is sprueless, so as to avoid the complexity and wastage associated with forming and discarding plastic sprues. The method makes advantageous use of back pressure at the gate entrance to reduce filling speed of the resin into the cavity. The design leaves the bushing or duct for injecting the resin unobstructed by any mechanical means, while at the same time providing for secure and reliable shut-off of the gate.

The shut-off method is such as to permit ready separation of the mold halves with no leakage of resin that has to remain in a molten state inside the nozzle and with no material left on the gating means after the injection that may be injected during a subsequent molding operation in the mold. The configurations of the mold bushing or mold injection nozzle and the valve gating means or shuttling plug enable them to be readily customized to accommodate various molding variables and resins.

For many applications, the bores will be circular and have the same diameter as dictated by the outer diameter of the shuttling plug that creates the hole in the molded article. The mold injection nozzle can include an elongated nozzle housing comprising a cylindrical body portion for sliding movement within the first bore. The shuttling plug preferably includes a main cylindrical body portion for sliding movement in the first and second bores. For some applications that do not require circular holes, the body portion may have other desired cross-sectional geometry such as non-circular (ellipse, etc.) or polygonal (square, pentagon, etc.)

More preferably, the shuttling plug includes a head portion including the first surface of the shuttling plug, and the tip portion and the head portion include second, complementary, sealing surfaces and the displacement means is adapted to displace the second sealing surface of the head portion against the second sealing surface of the tip portion to shut off the mold gate. Further, to form the hole, the first and second bores are advantageous coaxial with one another, and the shuttling plug then includes a body portion having a cross-section corresponding to the cross-section of the hole in the article and to the cross-sections of the first and second bores, for passing through the article and from the first bore into the second bore, to form the hole under the action of the displacement means.

The cylindrical, or other body portion of the shuttling plug, is then partly located in the cavity mold and thus acts as a core during the injection of the molten resin. The shuttling plug also can include an upper portion that may have various geometrical shapes as dictated by optimum guiding requirements of the flow of the molten resin entering the cavity mold. This upper portion of the shuttling plug also comprises first and second surfaces which cooperate with first and second surfaces of the injection nozzle to provide several different functions: firstly to act as a core; secondly, to create the mold gate that may have an adjustable thickness or height and thirdly to securely shut-off the flow of molten resin

achieved by the movement of the shuttling plug towards the injection nozzle tip, causing the second surfaces to abut one another.

The nozzle channel of the mold injection nozzle is conveniently provided in the elongate nozzle housing and extends generally axially towards the cavity mold. The mold injection nozzle may comprise several functional portions that have to cooperate and thus have to match the features of the machine injection nozzle, the features of the mold and the features of the shuttling plug.

The nozzle outlet is then provided at a free end of the elongate nozzle housing and comprises a surface that is continuous with the nozzle channel and, in section, curves from an axial direction to a substantially radial direction. This surface, in section, is preferably generally rounded. This ensures that the resin flows smoothly without adverse shear conditions being generated and without forming weld lines in the finished article.

Preferably, the plug has a head portion, corresponding to the profile of the nozzle outlet surface and, in section, providing a curved, concave head surface, the concave surface of the head portion abutting the nozzle outer surface at peripheries of the nozzle outlet and head surfaces. The nozzle head and outlet surfaces are such as to create a circular mold gate passage that tapers progressively down in height or thickness from the axis of the nozzle channel to the periphery of the mold gate passage. As the mold gate passage reduces in height, the circumference of the passage increases so that there need be little variation in the flow velocity of the resin through the passage.

Preferably, the apparatus includes a plunger and an actuating unit, mounted in the second mold half, with the actuation unit connected to the plunger for displacement of the plunger, the plunger being mounted to drive the plug from the second bore through the mold cavity into the first bore.

The plug can have a variety of different shapes for the head portion thereof. This head portion can be a generally domed, spherical surface.

Alternatively, it can include a planar top surface, or the head surface may be conical. The head portion of the plug can have a height that is greater than half the radius of the main cylindrical body portion of the plug.

In accordance with another aspect of the present invention, there is provided, in combination: injection molding equipment comprising a first mold half, a second mold half, a first bore extending through the first mold half and a second bore, aligned with the first bore and extending through the second mold half, the first and second mold halves defining a mold cavity for molding an article including a hole; and an injection nozzle apparatus comprising:

a mold injection nozzle defining a nozzle channel for resin which nozzle channel has a nozzle inlet for connection to a machine injection nozzle and a tip portion for communication with the mold cavity, the mold injection nozzle mounted for sliding movement in the first bore between a molding position adjacent the second mold half and a second position spaced away from the second mold;

an independent shuttling plug slidably mounted in the second bore facing the tip portion, wherein the tip portion and the shuttling plug include first surfaces facing one another to form a mold gate; and

displacement means secured to the second mould half and being for displacing the shuttling plug relative the tip portion for varying the spacing between the first surfaces to vary the width of the mold gate, said displacement means being mounted in the second mold half separate from the shuttling plug.

In yet another aspect the present invention provides an injection molding method for forming articles including an aperture therethrough, comprising bringing together first and second mold halves to a closed position to form a mold cavity space of thickness T1;

placing an injection molding nozzle comprising an uninterrupted melt channel, a tip provided with gating means and located inside a bore in the first mold half, in its molding position;

moving an independently sliding gate valve means located in a bore in the second mold half to its molding position until thickness T2, of a circular mold gate formed in cooperation with the gating means of the nozzle, corresponds to the thickness T1 of the mold cavity space;

allowing molten material from a supply means to flow through the nozzle melt channel in tubular flow;

converting the tubular flow to annular flow as it encounters the sliding valve gating means located at least partly in the first bore;

further converting the annular flow into radial flow when it encounters the circular mold gate and thereafter enters the mold cavity space;

forming an aperture in the article with mold core means associated with the sliding gate valve means;

and after the cavity has been filled with resin and the resin is at least cooled to form a molded article, moving the nozzle to its post molding position and the valve gate means to its post molding sealing position to seal the nozzle channel to prevent leakage of molten material in the mold opened position.

In another aspect the invention provides a method of injection molding sprueless articles with no weld lines and having a through hole using a valve gated mold injection nozzle and a mold having a first stationary platen and a second platen forming a mold cavity space in the mold closed position, comprising the steps of:

injecting a molten material through the melt channel of the mold injection nozzle from an inlet portion in communication with a source of material and up to an outlet portion in communication with the mold cavity comprising a central mold element, wherein the melt has a tubular flow pattern;

converting said tubular flow pattern, into an annular flow pattern at the outlet portion of the nozzle through the use of said mold element located at least partially inside the melt channel;

further converting said annular melt flow pattern into a radial melt flow pattern entering the mold cavity space through a circular gate substantially free of mechanical obstructions, said radial flow pattern being generated by said mold element;

shutting-off the flow of molten material by completely moving said mold element from its core position in the movable mold platen towards the mold injection nozzle in the stationary mold platen;

cooling the mold, opening the mold and releasing a molded article.

A further aspect of the present invention provides a method of injection molding an article in a mold comprising first and second mold halves, which are movable between an open position in which a molded article can be removed from a mold cavity and a closed position defining the mold cavity, the first mold half having a first bore and the second mold half having a second bore, which second bore is aligned with the first bore at least in the closed position, a mold injection nozzle slidably mounted in the first bore for movement between a molding position adjacent the second mold half and a second position spaced away from the second mold half, and a plug slidably mounted in the second bore, the method comprising the mold injection nozzle and the shuttling plug including facing first surfaces that define a mold gate, the method comprising the steps of:

(1) bringing the first and second mold halves together to the closed position to form the cavity with the mold injection nozzle in the molding position;

(2) controlling the position of the plug relative to the injection nozzle, to vary the width of the mold gate formed between the first surfaces;

(3) injecting resin through the mold injection nozzle and the mold gate to fill the mold cavity;

(4) after the cavity has been filled with resin and the resin at least cooled to form a molded article, opening the cavity to and removing the molded article.

Preferably, the injection nozzle and the shuttling plug are controlled to maintain the mold gate at a desired location within the cavity.

After molding, the injection pressure is cut-off and the machine's injection nozzle is then retracted and the mold is opened. Spring biasing means provided for the mold injection nozzle then maintain the nozzle tip portion in the second position and in tight contact with the shuttling plug with no leakage of resin. The article can then be ejected from the mold using known ejection means and then removed out of the mold area using known robotics means. Additionally, with the resin flow shut off, this ensures that the shuttling plug is retained in the first bore closing off the mold injection nozzle.

After the article has been removed, the first and second mold halves are returned to the closed position forming the mold cavity. The machine injection nozzle is advanced again, causing the mold injection nozzle to return to the molding position and driving the shuttling plug back into its initial position, more exactly partly inside the mold cavity and also partly inside the second bore. Simultaneously, according to a preferred aspect of the current invention, a fluid powered mechanism for displacing the plug is retracted in its initial position.

To control flow of resin into the mold cavity, the position of the plug relative to the nozzle outlet is controllable in real time and could be adjusted to define the width of a mold gate passage function of the plastic resin to be used, the actual injection machine operating the mold and the injection molding parameters. It has to be mentioned that the mold according to the current invention and the molding method are operable using a broad range of plastic materials to produce a variety of weld line free plastic articles having accurate holes, using either horizontal or vertical injection molding machines. The present invention provides cold sprue quality melt flow, but without the wasted cold sprue and the equipment needed to eliminate it from the part.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings which show preferred embodiments of the present invention and in which:

Figure 1 is a vertical, sectional view of a first embodiment of an apparatus in accordance with the present invention;

Figure 1a is a detail of a second embodiment of a motive means used to actuate a shuttling plug.

Figure 2 is a sectional view similar to Figure 1, showing a nozzle gate assembly in closed position;

Figure 3 is a sectional view similar to Figure 2, showing separation of mold halves;

Figures 4a and 4b are detailed, sectional views, showing one profile for a nozzle bushing and a shuttling plug;

Figures 5a to 5l show schematic views, showing a number of alternative profiles for the nozzle bushing and the shuttling plug as shown in the previous Figure;

Figure 6 shows a vertical sectional view through a further variant of the closure plug;

Figure 7 shows a vertical sectional view through a further variant of the shuttling plug;

Figure 8 shows a plan view of a disc with a non-circular central hole;

Figures 9a and 9b show a side view of a shuttling plug for forming a non-circular hole and a plan view of the closure plug for forming a non-circular hole;

Figures 10 and 11 show plan views of circular articles showing different profiles of non-circular through holes; and

Figure 12 shows an alternative mechanism for retaining a shuttling plug in second position when the mold is opened.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

MOLD DESIGN

Referring first to Figure 1, a mold assembly in accordance with the present invention is indicated generally by the reference 10. The mold assembly 10 includes, in known manner, a first mold half 14 and a second mold half 16. The mold halves 14, 16 define a mold cavity space 18.

It will be appreciated that, for convenience, the mold assembly 10 is shown in a vertical position in Figure 1. However, the mold can be oriented in any suitable way, which will often be governed by the particular injection molding equipment used. Thus the mold could be arranged horizontally. Also, either one or both of the mold halves, 14, 16 can be movable, although in this embodiment the mold half 14 is movable.

At the top of the mold half 16 there is a substantial recess 26 which continues into a bore extending through the mold half 16, the bore comprising a first bore portion 28 of relatively wide diameter and a second bore portion 30 of relatively small diameter.

A slidable mold injection nozzle 32 has a nozzle head portion 34 providing a shoulder that abuts against the mold plate 16. The nozzle head 34 also includes an outer sleeve 35 that slidably engages the first bore portion 28. Outside of the sleeve 35, there is an annular slot 36, and a compression spring 37 acts between the nozzle head 34 and the mold plate16.

The injection nozzle 32 further comprises a nozzle housing 38 having an axial nozzle melt channel 40 for feeding the molten resin into the mold cavity space, the nozzle 32 further having a nozzle inlet portion 42.

A machine injection nozzle 44 abuts this nozzle inlet 42. The spring 37 maintains the head portion 34 of the mold injection nozzle and the machine injection nozzles 44 in sealed contact and in fluid communication with one another, and has a spring rate and size such that, contact between them is maintained without drool during the injection process. The machine injection nozzle 44 and consequently the mold

injection nozzle 32 are moved in known manner by means not shown between an injection position shown in Figure 1 and a post injection position shown in Figure 2.

As shown in more detail in Figure 4a, the free end of the elongate nozzle housing 38 continues into a nozzle tip portion 50. The tip portion 50 comprises a gating portion 52, that cooperates with the plug 90 described below, to define a mold gate.

The tip portion 50 further comprises an outer sliding surface 54. In one embodiment, within the fixed mold half 16 and facing the mold cavity 18, there is a second cylindrical bore 56. that faces downwardly.

According to one aspect of this current invention, within this bore 56, there is a sleeve 58 made of a suitable thermal insulating material (such as titanium or titanium alloys) defining an internal cylindrical bore 60, as part of the second bore portion 30, along which the cylindrical surface of the nozzle tip 54 slides, and the shuttling plug 90 slides.

Turning now to Figure 1 for further details of the mold 10, a bore 72 extends through the movable mold half 14, and includes, adjacent the mold cavity 18, a portion of enlarged diameter. The mold according to this invention may be used to form "blank" discs with no pits that can be later on bonded to an information carrier discs to form a certain type of DVD or other type of molded disc. In this case the mold does not comprise a stamper plate 74 and means to retain and eject the stamper plate. In a preferred embodiment and in known manner, a stamper plate 74 known in the art is mounted inside the cavity space located on the moveable mold half 14 and is secured by a retention cylinder 76, which is fixed in position.

The retention cylinder 76 defines an internal bore within which an ejection cylinder 78 is slidably mounted. An actuation unit (not shown) is provided for driving the ejection cylinder 78 upwardly to eject a molded disc in known manner.

The ejection cylinder 78 defines an internal bore 80 having a first bore section 82 of relatively small diameter and a second bore section 84 of relatively large diameter. In one embodiment, a fluid drive unit 86 is

connected to a plunger 88 for displacing a shuttling plug 90, which is an innovative and very accurate component of the mold design in accordance with the present invention. The plunger 88 simply abuts the plug 90 and is not secured to the plug 90. As further shown schematically in Fig. 1a) in some detail, the actuation of the plunger 88 can be effected by other constructions, for example in a more accurate and secure manner by a wedge mechanism 105 actuated by fluid 103 or other suitable means. The movement of the wedge is limited by a movable pin 107 operated by fluid actuating means 109 during the injection step. Means not shown are used to keep the plunger 88 in permanent contact with the wedge.

During the sealing process of the nozzle by the shuttling plug 90, the wedge is further moved by passing the pin 107 up to a second stop pin 101 that is stationary. Means not shown, but known in the art may be used to monitor from outside the mold the position of the wedge or/and of the plunger and the position of the mold injection nozzle in order to determine exactly the thickness of the gate. Functions of the molding conditions and the thickness and the position of the gate can be adjusted without interrupting the molding process with high accuracy.

SHUTTLING PLUG DESIGN

The shuttling plug 90 is initially located in the movable mold half and serves several critical functions, as detailed below, namely to form in conjunction with the nozzle tip a circular mold gate with no mechanical obstructions, to guide the incoming tubular flow of molten material and change it from a tubular flow into a radial flow filling the mold cavity space, to act at least partially as a core and thus form at least partially a through hole in the of a disc and finally to seal off the mold gate through its move into the stationary mold half, at least partially, until it makes a seal contact with the nozzle tip portion of the movable mold injection nozzle.

According to the current invention, the position of the circular gate relative to the mold cavity space and its thickness can vary, as dictated by the actual injection molding parameters and by the specific material to be molded. Details of one variant of the plug 90 are shown in Figures 4a and

4b. As shown, the plug 90 has a sliding and coring body portion 92, a passive portion 91 facing plunger 88 and a gating portion 94 facing the injection nozzle tip. In one preferred embodiment, plug 90 is formed as a body of revolution and the upper gating portion 94 comprises an apex 96. This apex engages the incoming tubular flow of resin before it reaches the nozzle tip portion to facilitate the smooth conversion from a tubular flow to a radial flow while having for a short distance an intermediate and transitional annular flow between the tubular and radial flow patterns.

As shown in Figures 1 and 4a, in cross section, upper portion 94 comprises in one embodiment a curved surface of revolution 93. This curved surface is shaped to cooperate with the gating portion 53 of the nozzle tip portion 50 so that together form a melt channel 98 terminating with the circular mold gate 95 of a thickness T.

Surface 93 can actually have various shapes function of the specific molding application as shown in more detail in Figs. 5a to 5j. The shapes of this surface are always selected based on computerized melt flow analysis in such a manner as to serve several functions: e.g., seal the gate in conjunction with the nozzle tip, transform the incoming tubular flow into an annular flow and finally converting it into a radial flow entering the cavity space through a circular gate with no turbulence.

In most instances it is desirable to achieve a minimum contact area between the nozzle tip gating portion 53 and the shuttling plug gating portion 94, and preferably that area is reduced to a circle. This allows for improved sealing and also minimum contact between the two abutting surfaces that contribute to rapid disengagement of the plug and the nozzle prior to each injection step. Also by having minimum contact, substantially no material is left on either the plug or the nozzle after each injection step.

As shown in more detail in Fig. 4b, the angular difference between the gating surfaces of the plug and nozzle tip provides the benefit that substantially no molding material is returned into the melt channel of the nozzle by the movement of the plug to seal the gate. This is a critical requirement especially when molding information carrier substrates used

with light based readers. As further shown in Fig. 4a the nozzle tip and the upper portion of the plug 94 form a "virtual" and circular mold gate that has no mechanical obstruction. This is a unique feature not contemplated by the prior art whereby the resin flows in a tubular flow completely unobstructed through an injection nozzle located into a first mold half up to the nozzle tip where it is converted first into an annular flow and then into a completely unobstructed radial flow that is further injected through a circular mold gate into a cavity space and wherein the flow of resin is interrupted after filling the cavity space by a valve gating means located outside the nozzle melt channel that is movable against the nozzle tip and wherein the nozzle tip and the valve gating means form said unobstructed circular mold gate. Substantially no molding material is removed by the displacement of the shuttling plug inside the cavity space during its movement towards the nozzle tip to shut-off and seal the gate after the injection step.

The nozzle housing 38, in the advanced or molding position, is located so that the tip portion 50 is positioned a distance h1 below the top of the mold cavity 18. The gate passage 98, at its outlet, has a height h2, and is positioned generally centrally in the cavity 18, so that the resin flow will uniformly fill the top and bottom of the cavity 18. A unique feature of the present invention is that both the position of the gate within the cavity 18, i.e. the height h1, and the gate height h2, are independently variable.

As shown in Figure 4b, the plug 90 can be brought into abutment with the tip surface 52, to close off the tip portion 502. Due to the tapered profile of the mold gate passage 98, sealing occurs at the outer periphery of the head surface 94 and the tip portion 50, along second sealing surfaces generally indicated at 100. These second sealing surfaces 100 can either be essentially a nominal line contact, or the surfaces can be configured to provide sealing surfaces having a desired radially extent, i.e. being generally annular.

As detailed below, the plug 90 is displaced by the plunger 88 driven by the fluid drive unit 86. The drive unit 86 comprises a cylinder defining a

first chamber 102 and a second chamber 104 separated by a piston 106, which is connected to the plunger 88. Appropriate connections 108 are provided for connection to a fluid supply, for operation of the piston 106 in known manner. The piston 106 works in conjunction with the movement of the machine nozzle 44 and has two functions. One function is to move the plug 90, which shuttles back and forth, and the other function is to form an adjustable stop, i.e. to oppose the molding pressure to the molten resin and the resistance of the actual spring 48 when the plug 90 travels within the guide bushing 58. As shown in Figure 1a, the same function can be achieved by using a wedge design.

The mold assembly 10 can be heated and cooled in known manner. Thus, for this purpose, the fixed and movable mold halves 14, 16 are provided with cooling channels 110. Similarly, an elongate cylindrical heating element 112 is provided around the elongate nozzle housing 38, and other heaters can be provided, to maintain resin within the mold injection nozzle 32 molten.

In use, the mold assembly 10 is in the closed position at the start of a cycle as shown in Figure 1, with the mold injection nozzle 32 in the molding position, namely with the tip portion 50 adjacent the cavity 18, as maintained by the mechanical pressure of the machine nozzle applied to the mold nozzle. The molten resin is injected under pressure from the machine injection nozzle 44, through the nozzle channel 40 and the mold gate passage 98 into the mold cavity 18. It can be noted that the combination of the various channels provides a smooth, continuous channel, which has no abrupt changes in section and which shows no obstructions in the channel. This design avoids problems due to varying shear history within the material and the generation of weld lines which can result in birefringence. The circular mold gate passage 98 can be such as to create a back pressure and reduce the velocity of the molten resin filling the mold cavity 18.

As shown in Figure 4a, during filling of the mold cavity 4a, the piston 106 with the plunger 88 can be operated to maintain the plug 90 in

a desired location, so as to control the width or height h2 of the mold gate passage 98. Thus, the mold gate passage 98 can be varied in section, depending on variations in various parameters. For example, the viscosity of the resin will vary with temperature and the pressure which resin is delivered will vary. The width of the mold gate passage 98 can be varied to ensure a uniform and desired filling rate of the mold cavity 18. Again, if the mold cavity 18 is filled too quickly, the problems with weld lines and birefringence can occur. As shown in Figure 1a, the same function can be achieved by using a wedge design.

As shown in Figure 4a, the width of the mold gate passage 98 is measured by the axially spacing h2 at the outer circumferential periphery of the mold gate passage 98. At all times, the heating element 112 is operated to maintain resin within the nozzle channel 40 molten.

After injection of molten resin is stopped by switching off the injection molding machine, the plug 90 is displaced by the piston 106 and plunger 88. The plug 90 travels through the distance h2, to complete the formation of a central hole 116 in the disc, indicated at 114, this hole having a diameter corresponding to the diameter of the cylindrical body portion 92 of the plug 90. The plug 90 then abuts and seals off the tip surface 52, as shown in Figure 4b.

The plug 90 is continuously displaced by the piston 106 until it has been displaced a further distance L (see Figures 2,3 and 4b). Simultaneously, the mold injection nozzle 32 and machine injection nozzle 44 are displaced backwards by the same distance L, to allow the plug to enter fully over its full length within the guiding sleeve or bushing 58, as shown in Figure 2. The injection nozzle 32 has then reached the second position, in which the tip portion 50 is spaced from the mold cavity 18. Also, the machine injection nozzle is retracted, so it is not urging the mold injection nozzle into the molding position.

The spring 37 ensures that the mold and machine injection nozzles 32, 44 are always in contact with one another. The mold 10 is cooled to solidify the disc 114. During this time, the outlet or tip portion 50 is

maintained closed. This has a number of advantages. Firstly, the mold injection nozzle 32, which is maintained hot is displaced away from the mold cavity 18, where cooling of the disc continues. This ensures that resin at the tip of the nozzle can be maintained hot ready for the next cycle, without being affected by further cooling of the disc just formed. Throughout this motion the good seal created between the plug 90 and tip surface 52 is maintained. This prevents contamination of the next shot of material into the mold cavity.

With the disc 114 fully solidified, the mold is then opened as shown in Figure 3. The plunger 88 is then retracted to clear the hole 116 in the disc 114. As the machine injection nozzle 44 has been retracted, the mold injection nozzle 32 is maintained in the second position by the spring 37. A significant feature of this opening step is that the plug 90 cannot drop since it is kept inside the guiding sleeve 58 by frictional forces and also due to the gluing effect exercised by the thin film of molten resin in the tapered area between the plug and the nozzle. In another embodiment, shown in Figure 12 and described below, some mechanical means is used to securely maintain the plug inside the guiding sleeve 58. As the resin supply is shut off, the plug 90 cannot drop since there is no path to permit air to break the seal between the plug 90 and the resin within the conduit 40. The mold is open by a distance D, greater than the distance L, to provide room for a part removal robot. With the mold open, the disc 114 can be removed by a robot arm or the like in known manner.

The mold halves 14, 16 are then closed again. The piston 106 is again controlled to form a mold gate passage 98 with a desired gate height h2. Another disc 114 can then be molded as above.

An important aspect of the present invention is the configuration of the tip portion 50 and the head surface 94 of the plug 90. As shown in other figures, the head surface 94 can have a variety of configurations, and correspondingly, the tip surface 52 can have a number of different configurations. Generally, these include first surfaces that define the mold gate, and second sealing surfaces for abutting one another to close the

gate. The sealing surfaces provide either a nominal line contact or an annular sealing surface, which preferably extends radially inwards from the outer peripheries of the tip portion 50 and the plug 90.

Referring first to Figure 5a, there is shown a combination of a plug 90a and tip surface 52a, where the plug 90a has a head portion 94a that shows concave surfaces, in section as the earlier embodiment. Here, the head portion has a height that is substantially greater than the diameter of the shuttling plug 90a, so as to extend a long way into the channel 40. This is done so as to provide a particularly smooth transition from the axial flow in the channel 40 to the radial flow from the gate passage 98.

Figure 5b shows a version of the plug indicated at 90b with a tip surface 52b, which have complementary concave and convex surfaces. Here, the plug 90b is shown with a height H1, a diameter D1 and a head portion 94b having a height K1 and a radius for the concave portion, in section, of R1. The various dimensions H1, D1, K1 and R1 would be related as desired. Thus, K1 could either be less than or greater than D1 as required; it will be appreciated that in the Figure 5a version, the dimension K1 can be a significant multiple of the dimension D1.

A shuttling plug 90c, in Figure 5c has a generally convex or domed shape with a head portion having a height K2. This cooperates with a tip surface 52c which correspondingly shows convex surfaces. These surfaces are configured to provide a nominal, sealing line, in the closed position, at the periphery of plug 90c and tip surface 52c.

Figure 5d shows a further variant, where a shuttling plug 90d again has a domed or rounded head surface. Here, this cooperates with a tip surface 52d having a complementary concave, curved surface, so that sealing is achieved over a substantial area.

A plug 90e in Figure 5e has a concave, curved head surface or portion indicated at 94e. Here, this cooperates with an tip surface 52e showing concave surfaces. This has the advantage of producing a large internal volume adjacent the gate, which may reduce shear effects immediately preceding the gate and be desirable for some uses.

Figure 5f shows a combination of a shuttling plug 90f showing a configuration similar to Figure 4a, with concave surfaces, and a tip surface 52f showing a rounded, concave end surface. These surfaces would again be configured to provide sealing at the radially outward peripheries thereof.

In Figure 5g, a plain, cylindrical plug 90g has a height or axially length H2 and a diameter D2, which would be related as desired. A tip surface 52g shows convex surfaces, and somewhat like Figure 5e, this would provide a large flow area immediately adjacent the gate.

Figure 5h shows a shuttling plug 90h, generally similar to plug 90g, in cooperation with a tip surface 52h generally similar to the tip surface 52f, i.e. with a curved, concave lower surface. Again, this would provide a sealing at the radial outer periphery.

Complementary conical profiles are shown in Figure 5i. Here, a shuttling plug 90i has a generally conical head surface 94i with a height K3. Correspondingly, a tip surface 52i is a complementary conical surface to provide sealing over the full extent of the surface.

Figure 5j shows a variation of this conical arrangement. Here, a shuttling plug 90j again has a conical surface, but with a lower height. The tip surface 52j corresponds to the tip surface 52i, so that a gate passage is provided that decreases in height in the radially outward direction, and sealing is provided at the outer peripheries of the plug 90j and tip surface 52j.

In Figure 5k, a shuttling plug 90k is generally cylindrical, as in Figure 5g, and is shown in conjunction with a tip surface 52k showing a conical surface, again as in Figures 5i and 5j.

Finally, in Figure 5l, there is shown a simple cylindrical plug 90l, in conjunction with a tip surface 52l showing a planar end surface, so that an outlet passage of uniform height would be formed, as shown.

Thus, it will be appreciated that a variety of shapes can be provided for the plug and the tip portion of the nozzle. Each of the plug and the nozzle can have any of a planar surface; a conical surface; a variety of

convex surfaces; and a variety of concave surfaces. Further, the surfaces of each can show combinations of concave portions, convex portions, planar portions and other profiles. The configuration could be such as to provide either a nominal line contact around the edge or at some other location, or sealing over a substantial radial extent. In all cases, the location of the tip portion determined by the dimension H1 in Figure 4a, can be varied, as can the height of the outlet passage 98, i.e., the dimension h2.

To optimize the performance of the plug, it can be provided with means to heat the plug, and also can be formed from materials which provide insulating and/or conductive capabilities. For this purpose, the plug can be made from two or more separate parts.

The plug can also be made using a high wear resistance material, such as tungsten carbide or other powder injection molded material. The plug may be replaced by manual or automatic means after a certain number of molding cycles. In a preferred embodiment, the plug can be removed using the same robot means (not shown) that may be used to change the stamper plate.

Thus, with reference to Figure 6, a plug 140 comprises a body part 142 forming most of the cylindrical body and a head part 144 forming the head and part of the cylindrical body. The body part 142 could be formed from an insulating material, such as titanium or a ceramic so as to maintain it cooler than the head portion, since it is remote from the molten resin. On the other hand, the head part 144, forming the head portion can be formed from a highly conductive material, such as copper-beryllium, so as to maintain a uniform, high temperature in the resin at all times. This should maintain a uniform temperature in the resin as it flows into the cavities. Also, when flow of resin is interrupted but a disc is cooling and the mold is opened etc., this helps to ensure that resin at the outer edge of the mold gate passage 98 is maintained at a temperature close to that of the resin in the nozzle channel 40, to maintain uniform properties in the resin.

Additionally or as well, appropriate coatings can be provided to enhance these effects. Thus, an insulating layer 146 can be provided around the cylindrical body portion 92 and a conductive layer 148 can be provided on the top of the head portion.

With reference to Figure 7, a further plug 150 is shown. This plug 150 comprises a central part 152 defining an internal recess 154 and also the surfaces of the head portion indicated at 156. The cylindrical body portion 92 is defined by an outer part 158. The central and outer parts 152, 158 can be formed, respectively, from conductive and insulating materials, as detailed above.

Here, a heating element 160 is placed within the recess 154. It is provided with contact pins 162 and a thermocouple 164 is also mounted within the recess 154 and correspondingly has its own contact pins 166. Thus, when the plug 150 is in the retracted position of Figure 1, the contact pins 162, 166 will contact corresponding pins. The abutting pairs of contact pins are provided with sufficient resiliency to accommodate the movement of the plug 150 as required to vary the gate height h. This ensures that the heating element 160 can be continuously operated during filling of the cavity 18.

To applicant's knowledge, this combination of materials, provision of a heating element and a thermocouple for temperature control are wholly new in this art. They are selected to ensure that the resin is delivered to the cavity uniformly, and at a constant temperature, and with minimum shear disturbance. This will all contribute to the formation of an accurate and stress-free hole in the of the disc or other molded article.

For some applications, it may be necessary for the hole formed in the of the article to have a shape other than a circular shape. For example, in the case of a gear, it may be desirable to form a hole with various splines for torque transfer to or from the gear. Such an arrangement is shown in Figures 8, 9a and 9b. In Figure 8, a disc or other circular article 170 has a hole 172 which includes four approximately square extensions 174. For this purpose a plug 176, having an

appropriate profile is provided with four square protrusions 178. In use, the plug 176 would slide into the sleeve or bushing 58. However, the protrusions 178 extend beyond the diameter of the sleeve 58 and would be located in the mold cavity during the molding process, so as to form the extensions 178 of the hole 172.

Figure 10 shows another variation. Here, a gear 180 has a single slot 182 for a key or spline to secure the gear to a shaft. In Figure 11, there is shown a gear 184 with numerous splines or threads 186 again for attachment to a shaft.

With reference to Figure 12, there is shown a mechanism for assisting in retaining the plug in the first or movable mold half 16. Here, the plug, indicated at 90a, is provided with an annular channel or waist portion 188. Spring-biased retaining pins 190 engage the plug 90a in the second position, i.e. as in Figure 3, to assist in holding the plug 90a in this position when the mold is opened.

According to the current invention, the shuttling plug 90 performs the additional mold core and the gating functions without displacing molten material back into the cavity space and the mold injection nozzle. Also, the mold injection nozzle is movable towards the machine injection nozzle to allow the shuttling plug to remain, at least partially inside the cavity space, and to allow for changing of the mold gate thickness and its position. According to the current invention, the shuttling plug does not travel inside the melt channel of the mold injection nozzle, as taught by Wilson ' 464, but inside the bore which guide the movement of the mold injection nozzle.

It will be apparent to the reader that various changes and modifications may be made to the constructions of the present invention without departing from the spirit and scope of the invention as set out in the subsequent claims. All such changes are encompassed by the claims.

I CLAIM

1. An improved injection molding apparatus for forming articles including an aperture therethrough, the apparatus including a first mold half having a first bore; a second mold half having a second bore substantially aligned with the first bore, wherein the first mold half and the second mold half form a mold cavity space in the mold closed position, said mold cavity space having a thickness T1 adjacent said first bore,
the improvement comprising a slidable mold injection nozzle located inside said first bore having a molding position and a post molding position, said nozzle including an inlet in fluid communication with a molten material supply means; an outlet including a nozzle tip, said nozzle tip having a gating portion and being in communication with said mold cavity space when the nozzle is in said molding position; and an unobstructed nozzle melt channel between said inlet and said outlet to guide the flowing molten material from the supply means towards the mold cavity space in tubular flow up to the outlet;
independently movable sliding valve gating means located in said second bore and having a molding position therein and a post molding sealing position in said first bore, said valve gating means including mold core means to form a hole in the article to be molded, means for converting the flow of molten material from tubular to radial in the mold closed position, and nozzle channel sealing means to prevent leakage of molten material in the mold opened position;
a circular mold gate of a adaptable thickness T2, said mold gate being formed in the mold closed position between the gating portion of the nozzle tip and said valve gating means,

said mold gate having no mechanical obstructions, whereby the maximum thickness T2 of said gate is substantially equal to the thickness T1 of the mold cavity space;

first motive means to slide the mold injection nozzle inside the first bore between said molding and said post molding positions; and

second motive means to slide the valve gating means at least partially from said molding position inside the second bore to said post molding sealing position inside the first bore.

2. An injection nozzle valve gating apparatus, for use in injection molding equipment including first and second separable mold halves which together define a mold cavity for molding an article including a hole, which first and second mold halves include respective first and second guide bores opening into the mold cavity and aligned with one another, the injection nozzle valve gating apparatus comprising:

a mold injection nozzle slidably mountable in the first bore and defining a nozzle channel for supplying a homogenous flow of resin which nozzle channel has a nozzle inlet for connection to a machine injection nozzle and a nozzle outlet adjacent the mold cavity, wherein the nozzle outlet includes a tip portion and is mountable for sliding movement in the first bore between a molding position in which the tip portion is adjacent the mold cavity and a second position in which the tip portion is spaced away from mold cavity;

an independent shuttling plug slidably mountable in the second bore facing the nozzle outlet, wherein the tip portion and the shuttling plug include first surfaces which face one another to form a mold gate; and

displacement means for displacing the shuttling plug relative to the tip portion for varying the spacing between the first surfaces to vary the width of the mold gate, said displacement means being mountable in the second mold half and being separate from the shuttling plug.

3. An apparatus as claimed in claim 2, wherein the shuttling plug includes a head portion including the first surface of the shuttling plug and wherein the tip portion and the head portion include second, complementary, sealing surfaces and the displacement means is adapted to displace the second sealing surface of the head portion against the second sealing surface of the tip portion to shut off the mold gate.

4. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the first and second bores are coaxial with one another, and wherein the shuttling plug includes a body portion having a cross-section corresponding to the cross-section of the hole in the article and to the cross-sections of the first and second bores, for passing through the article and from the first bore into the second bore, to form the hole under the action of the displacement means.

5. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the first and second bores are circular and have the same diameter, and wherein the body portion is cylindrical.

6. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the nozzle tip includes a first surface which is complementary to the first surface of the head portion, so as to reduce turbulent flow of the molten resin in the mold gate area.

7. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the second surfaces comprise a nominal line contact around peripheries of the shuttling plug and the tip portion.

8. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the second surfaces are annular.

9. An injection nozzle valve gating apparatus as claimed in claim 7, wherein the annular second surfaces extend radially inwards from peripheries of the tip portion and the shuttling plug.

10. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the plug has a head portion, having a curved, convex head surface, to define a mold gate passage that, in section, has a throat of relatively small height, with radially inner and outer portions having a greater height.

11. An injection nozzle valve gating apparatus as claimed in claim 7, wherein the nozzle outlet and the plug have complementary, narrow, annular sealing surfaces around the peripheries thereof, for closing off the nozzle outlet.

12. An injection nozzle valve gating apparatus as claimed in claim 3, including a bushing defining at least part of the first bore in the first mold half, in which bushing the mold injection nozzle is slidably mounted.

13. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the mold injection nozzle includes a shoulder for abutting the first mold half.

14. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the displacement means comprises a plunger and an actuating unit, mounted in the second mold half, with the actuation unit connected to the plunger for displacement of the plunger, the plunger being mounted to abut and to drive the plug from the second bore through the mold cavity into the first bore, whereby the plug can remain in the first bore when the mold is opened.

15. An injection nozzle valve gating apparatus as claimed in claim 13, which includes an ejection cylinder provided around the second bore and a second drive unit for displacing the ejection cylinder axially, to displace an article from the mold cavity.

16. An injection nozzle valve gating apparatus as claimed in claim 5, wherein the plug includes a head portion providing a generally domed, spherical surface.

17. An injection nozzle valve gating apparatus as claimed in claim 5, wherein the plug comprises a cylindrical body portion having a planar top surface, and wherein the nozzle outlet surface provides, around the periphery thereof, a complementary sealing surface.

18. An injection nozzle valve gating apparatus as claimed in claim 5, wherein the head portion of the plug is conical.

19. An injection nozzle valve gating apparatus as claimed in claim 5, including a bushing defining at least part of the first bore in the first mold half, in which bushing the mold injection nozzle is slidably mounted.

20. An injection nozzle valve gating apparatus as claimed in claim 5, wherein the displacement means comprises a plunger and an

actuating unit, mountable in the second mold half, with the actuation unit connected to the plunger for displacement of the plunger, the plunger being mounted to abut and to drive the plug from the second bore through the mold cavity into the first bore, whereby the plug can remain in the first bore when the mold is opened.

21. An injection nozzle valve gating apparatus as claimed in claim 19, which includes an ejection means for mounting in the second bore and a second drive unit for displacing the ejection cylinder axially, to displace an article from the mold cavity.

22. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the head portion of the plug has a height which is greater than half the radius of the main cylindrical body portion of the plug.

23. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the body portion of shuttling plug has a height greater than the diameter thereof.

24. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the plug includes at least one protrusion for forming a corresponding slot in an article.

25. An injection nozzle valve gating apparatus as claimed in claim 3, wherein the plug comprises a lower cylindrical body formed from a thermally insulating material and an upper head portion formed from a thermally conductive material.

26. An injection nozzle valve gating apparatus as claimed in claim 3, which includes an internal recess and both an electrical heating element and a thermocouple provided in the recess, wherein both

the electrical heating element and the thermocouple include contacts which enable electrical connections to be made thereto when the plug is in the second bore.

27. An injection nozzle valve gating apparatus as claimed in claim 25, wherein the plug comprises a central part defining a head portion and the recess, and an outer part defining an outer cylindrical body, wherein the central part is formed from thermally conductive material and the outer part is formed from thermally insulating material.

28. In combination: injection molding equipment comprising a first mold half, a second mold half, a first bore extending through the first mold half and a second bore, aligned with the first bore and extending through the second mold half, the first and second mold halves defining a mold cavity for an article including a hole; and an injection nozzle apparatus comprising:
a mold injection nozzle defining a nozzle channel for resin which nozzle channel has a nozzle inlet for connection to a machine injection nozzle and a nozzle tip portion for communication with the mold cavity, the mold injection nozzle being mounted for sliding movement in the first bore between a molding position adjacent the mold cavity half and a second position spaced away from the mold cavity;
an independent shuttling plug slidably mounted in the second bore facing the tip portion, wherein the tip portion and the shuttling plug include first surfaces facing one another to form a mold gate; and displacement means secured to the second mould half for displacing the shuttling plug relative to the tip portion for varying the spacing between the first surfaces to vary the width of the mold gate, said displacement means being mounted in the second mold half separate from the shuttling plug.

29. A combination as claimed in claim 27, which includes a first support plate secured to and supporting the first mold half and a second support plate secured to and supporting the second mold half.

30. A combination as claimed in claim 28, which includes a bushing mounted in the first bore extending at least partially through the first mold half.

31. A combination as claimed in claim 29, wherein the first bore comprises a first bore portion of relatively large diameter extending in the first support plate and a second bore portion of relatively small diameter extending through the bushing and wherein the mold injection nozzle comprises a sleeve slidably mounted in the first bore portion and an elongate nozzle housing slidably mounted in the second bore portion.

32. A combination as claimed in claim 30, wherein the mold injection nozzle includes a nozzle head and a shoulder on the nozzle head,.which abuts the first support plate in the molding position, and first spring biasing means between the first support plate and the shoulder urging the mold injection nozzle into the second position.

33. A combination as claimed in claim 31, including a machine injection nozzle having an outlet in communication with the inlet of the mold injection nozzle and being displaceable with the mold injection nozzle, the machine injection nozzle being provided with second biasing means maintaining the machine and mold injection nozzles in abutment with one another.

34. A combination as claimed in claim 29, which includes a heating element means around the mold injection nozzle and cooling channels in the first and second mold halves.

35. A method of injection molding an article in a mold comprising first and second mold halves and movable between an open position in which a molded article can be removed from a mold cavity and a closed position defining the mold cavity, the first mold half having a first bore and the second mold half having a second bore, which second bore is aligned with the first bore at least in the closed position, a mold injection nozzle slidably mounted in the first bore for movement between a molding position adjacent the second mold half and a second position spaced away from the second mold half, and a plug slidably mounted in the second bore, the mold injection nozzle and the shuttling plug including facing first surfaces that define a mold gate, the method comprising the steps of:

(1) bringing the first and second mold halves together to the closed position to form the cavity with the mold injection nozzle in the molding position;

(2) controlling the position of the plug relative to the injection nozzle, to vary the width of the mold gate formed between the first surfaces;

(3) injecting resin through the mold injection nozzle and the mold gate into the mold cavity;

(4) after the cavity has been filled with resin and the resin at least cooled to form a molded article, opening the cavity to and removing the molded article.

36. A method of injection molding an article in a mold as claimed in claim 34, wherein in step (2), the mold injection nozzle and the shuttling plug are controlled to maintain the mold gate at a desired location within the cavity.

37. A method of injection molding an article in a mold as claimed in claim 35, when carried out with a mold wherein the mold injection nozzle and the shuttling plug include complementary, second, sealing surfaces for closing off the mold gate, wherein, between steps (3) and (4), the shuttling plug is displaced towards the mold injection nozzle, to cause the second, sealing surfaces to abut one another to close off the mold gate.

38. A method of injection molding an article in a mold as claimed in claim 36, wherein, after closing off the mold gate, the shuttling plug is displaced from the first bore through the cavity into the second bore, to form a hole in the article.

39. A method of injection molding an article in a mold as claimed in claim 37, wherein the shuttling plug remains within the second bore during opening of the cavity in step (4).

40. A method of injection molding an article in a mold as claimed in claim 38, where, after step (4) and removal of the molded article, the first and second mold halves are brought together again into the closed position, and the shuttling plug is retracted from the first bore back into the second bore, to enable molding of another article.

41. A method of injection molding an article in a mold comprising first and second mold halves and movable between an open position in which a molded article can be removed from a mold cavity and a closed position defining the mold cavity, the first mold half having a first bore and the second mold half having a second bore, which second bore is aligned with the first bore at least in the closed position, a mold injection nozzle slidably mounted in the first bore for movement between a molding position adjacent the second

mold half and a second position spaced away from the second mold half, and a plug slidably mounted in the second bore, the mold injection nozzle and the shuttling plug including facing first surfaces that define a mold gate, the method comprising the steps of:

(1) bringing the first and second mold halves together to the closed position to form the cavity with a mold injection nozzle in the molding position;

(2) injecting resin through the mold injection nozzle and the mold gate into the mold cavity;

(3) after the cavity has been filled with resin and the resin at least partially cooled, displacing the plug from the second bore to bring the second sealing surfaces into abutment with one another to close off the mold and to form a hole in the article, and further displacing the shuttling plug from the second bore into the first bore to form a hole in the article; and

(4) opening the mold and removing the molded article from the cavity.

42. A method of injection molding an article in a mold as claimed in claim 40, wherein after step (3), the first and second mold halves are separated while maintaining the plug within the first bore of the first mold half.

43. A method of injection molding an article in a mold as claimed in claim 41, wherein, after the article has been removed, the first and second mold halves are returned to the closed position forming the mold cavity, the shuttling plug is retracted into the second bore and the mold injection nozzle is permitted to return to the molding position.

44. An injection molding method for forming articles including an aperture therethrough, comprising bringing together first and

second mold halves to a closed position to form a mold cavity space of thickness T1;
placing an injection molding nozzle comprising an uninterrupted melt channel, a tip provided with gating means and located inside a bore in the first mold half, in its molding position;
moving an independently sliding gate valve means located in a bore in the second mold half to its molding position until thickness T2, of a circular mold gate formed in cooperation with the gating means of the nozzle, corresponds to the thickness T1 of the mold cavity space;
allowing molten material from a supply means to flow through the nozzle melt channel in tubular flow;
converting the tubular flow to annular flow as it encounters the sliding valve gating means located at least partly in the first bore;
further converting the annular flow into radial flow when it encounters the circular mold gate and thereafter enters the mold cavity space;
forming an aperture in the article with mold core means associated with the sliding gate valve means;
and after the cavity has been filled with resin and the resin is at least cooled to form a molded article, moving the nozzle to its post molding position and the valve gate means to its post molding sealing position to seal the nozzle channel to prevent leakage of molten material in the mold opened position.

45. A method of injection molding sprueless articles with no weld lines and having a through hole using a valve gated mold injection nozzle and a mold having a first stationary platen and a second platen forming a mold cavity space in the mold closed position, comprising the steps of:
injecting a molten material through the melt channel of the mold injection nozzle from an inlet portion in communication with a

source of material and up to an outlet portion in communication with the mold cavity comprising a central mold element, wherein the melt has a tubular flow pattern;
converting said tubular flow pattern, into an annular flow pattern at the outlet portion of the nozzle through the use of said mold element located at least partially inside the melt channel;
further converting said annular melt flow pattern into a radial melt flow pattern entering the mold cavity space through a circular gate substantially free of mechanical obstructions, said radial flow pattern being generated by said mold element;
shutting-off the flow of molten material by completely moving said mold element from its core position in the movable mold platen towards the mold injection nozzle in the stationary mold platen;
cooling the mold, opening the mold and releasing a molded article.

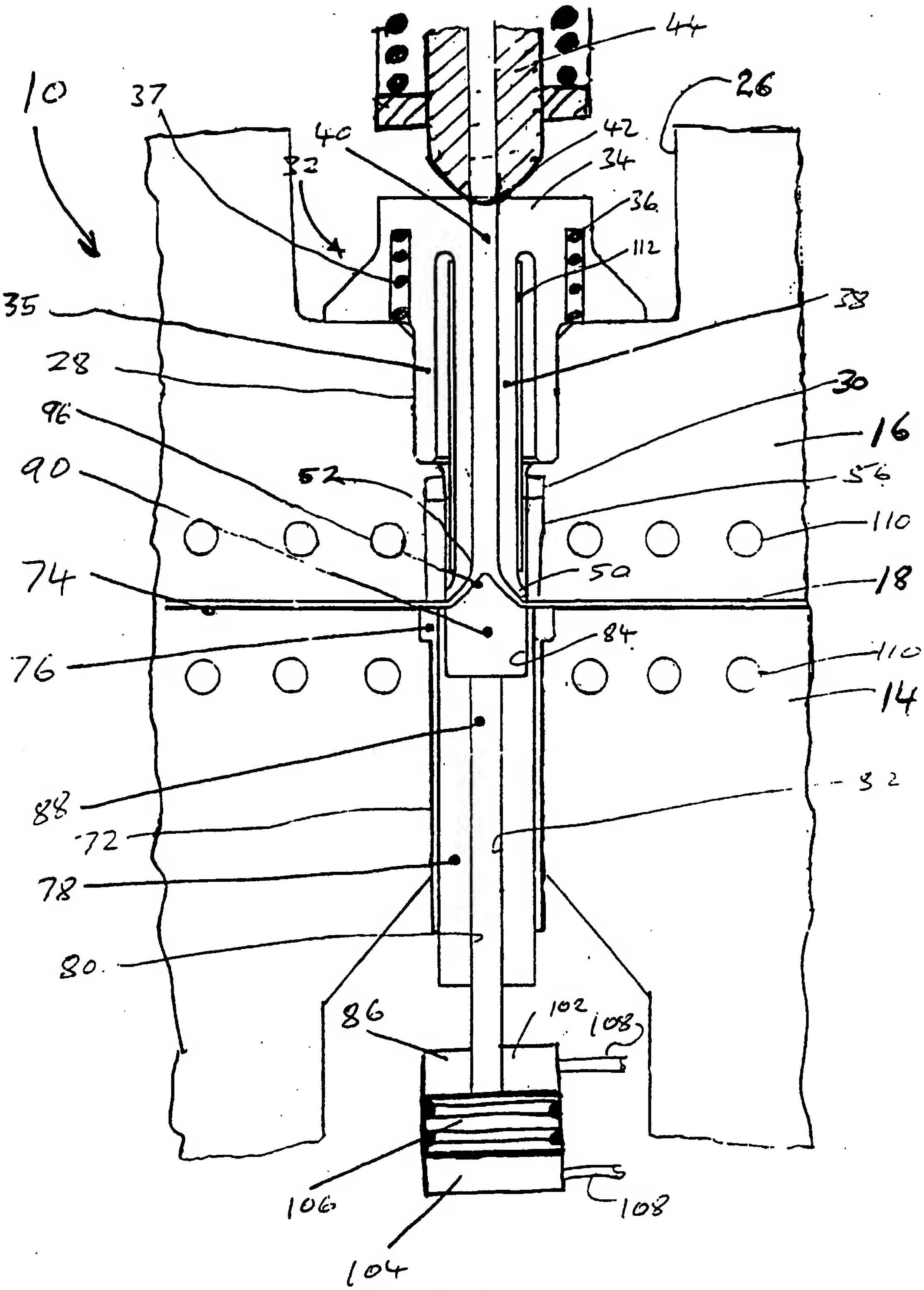
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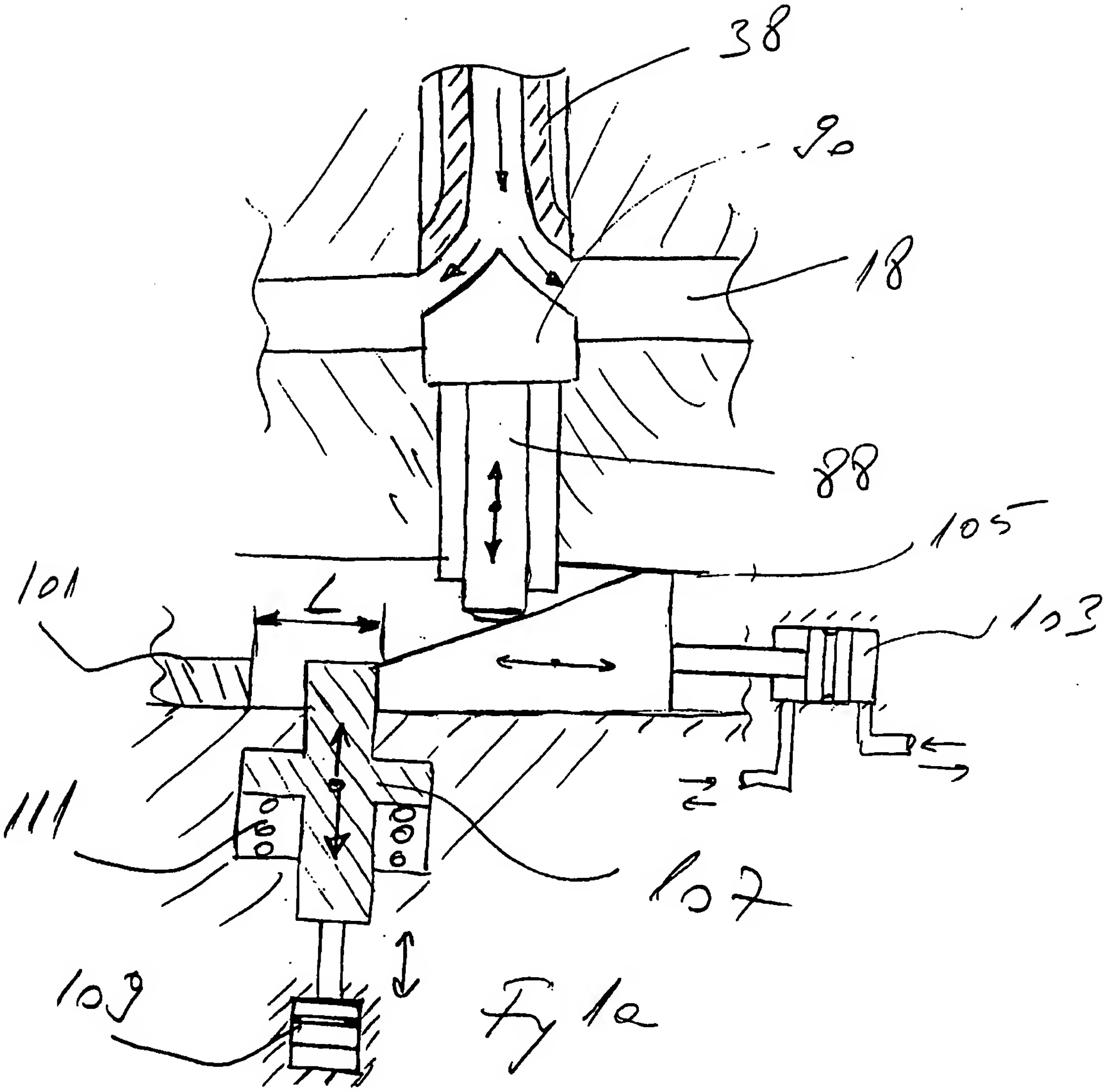
FIG. 1



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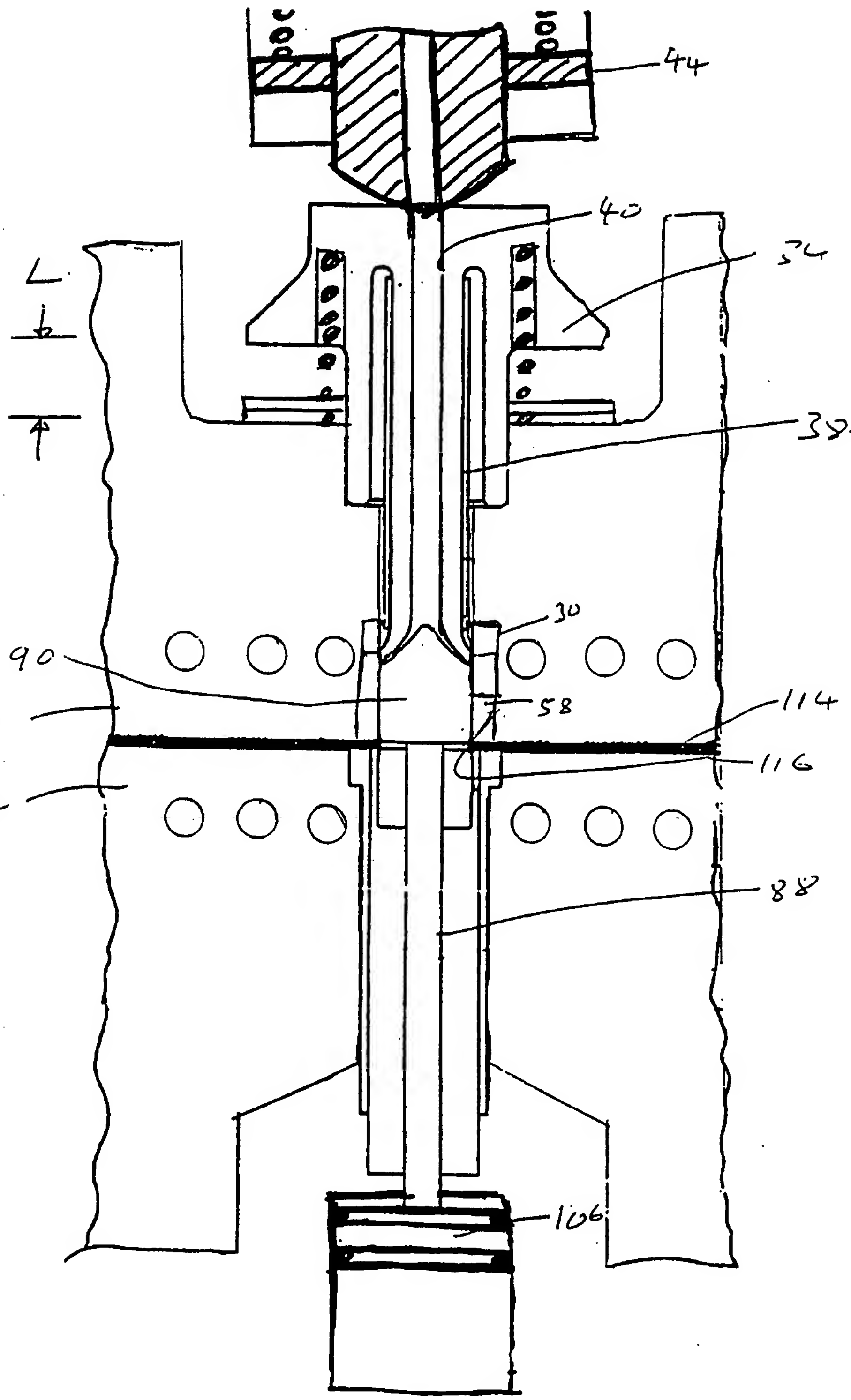
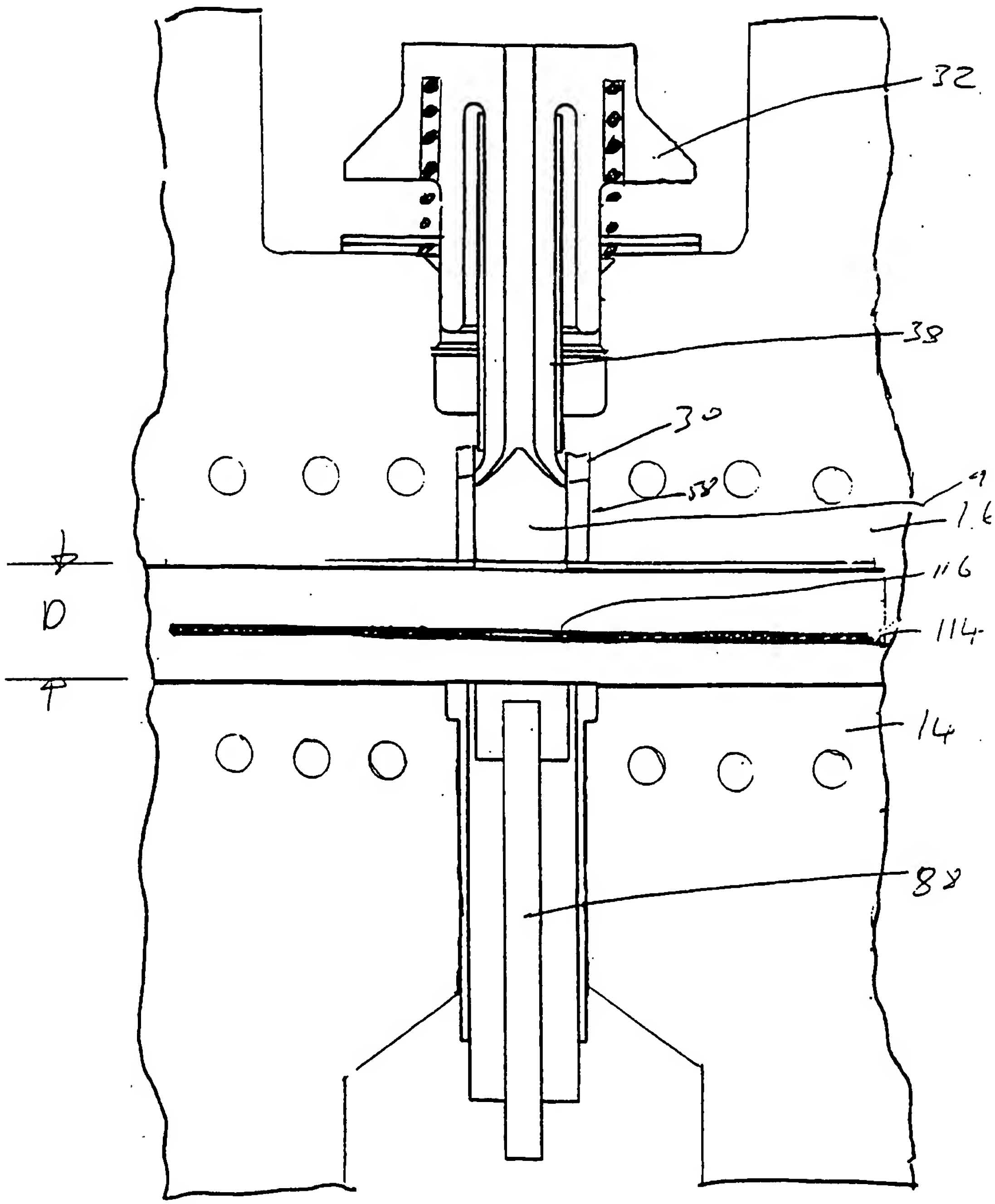


FIG. 2.



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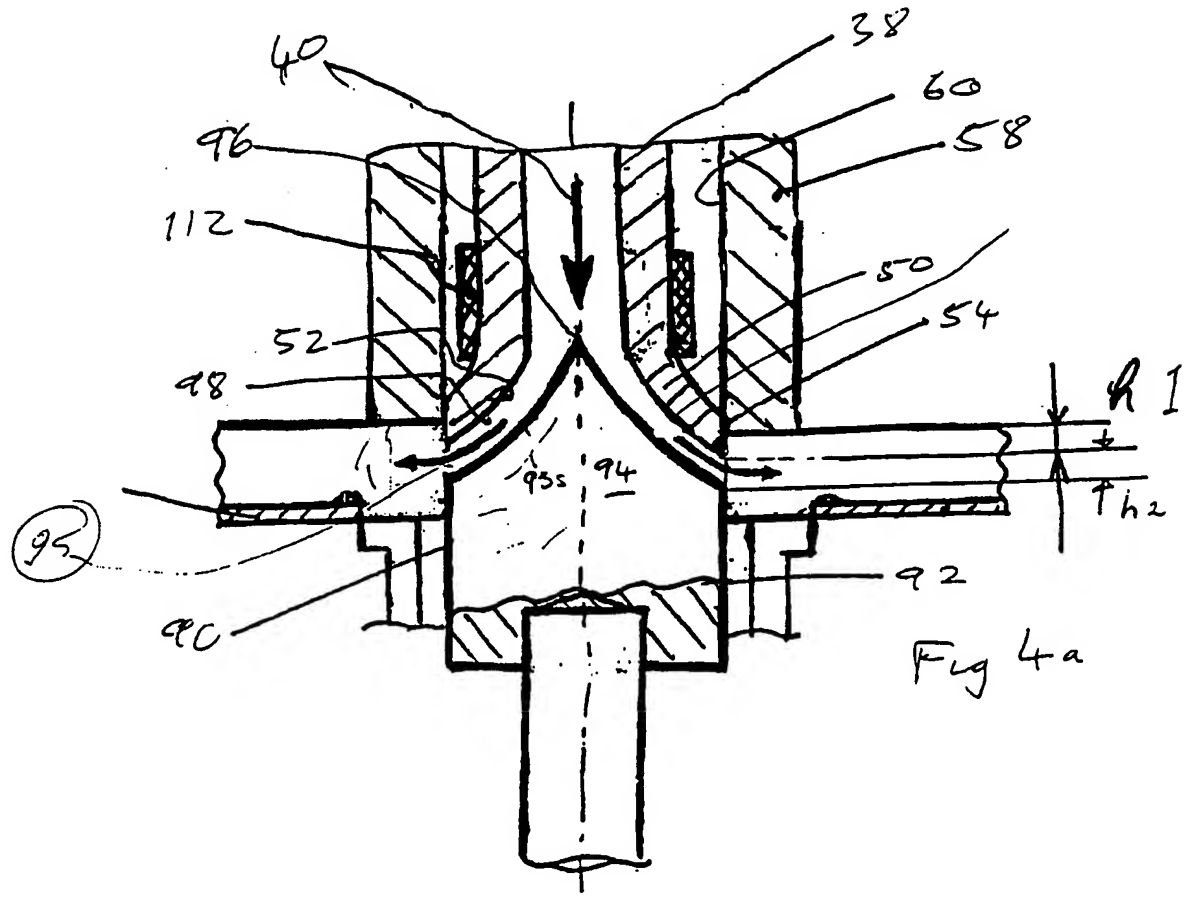
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Fig 4a

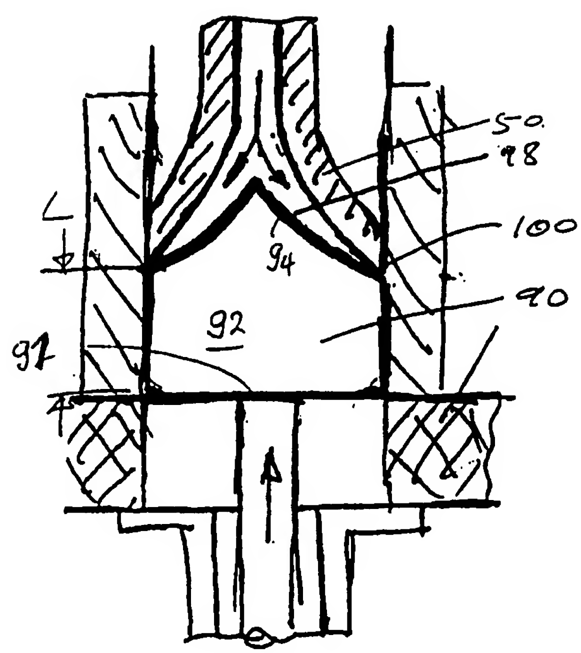
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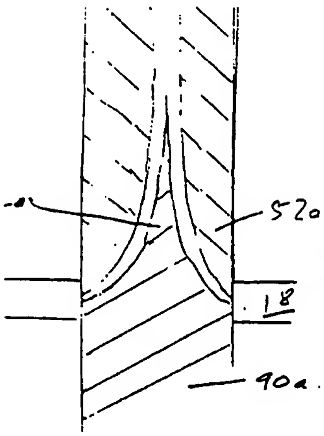
Fig 4b



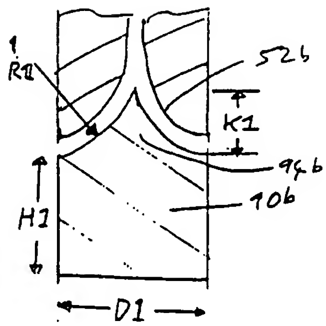


Figure 5b.

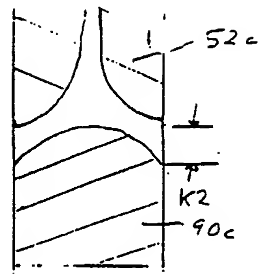


Figure 5c

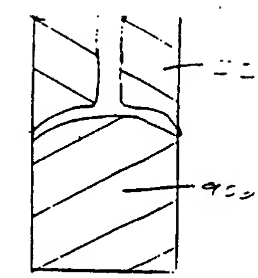
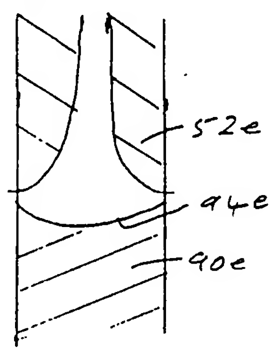
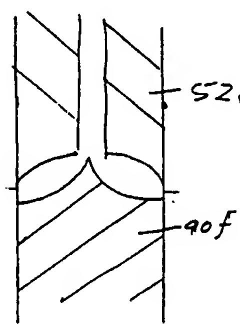
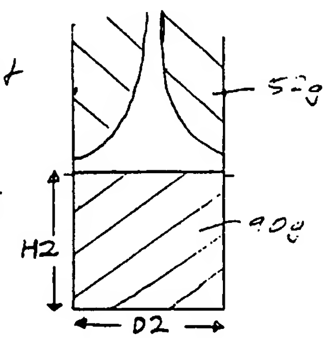


Figure 5d

Figure 5a







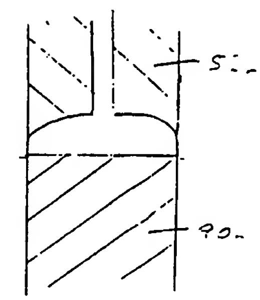
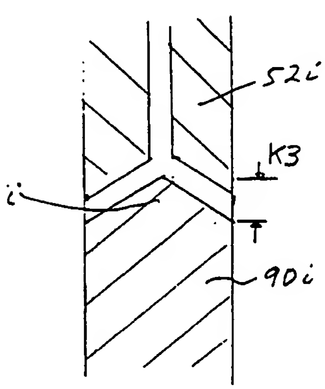


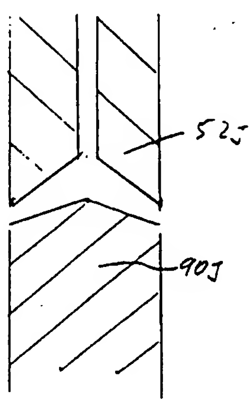
Figure 5e

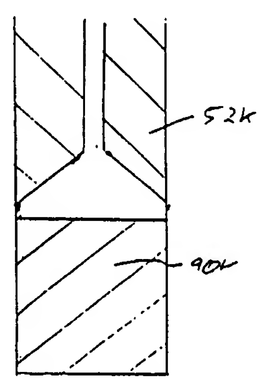
Figure 5f

Figure 5g

Figure 5h







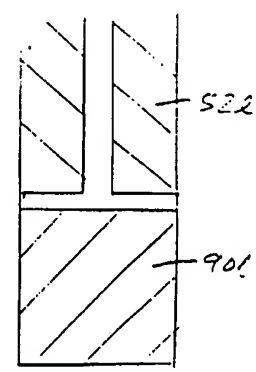


Figure 5i

Figure 5j

Figure 5k

Figure 5l

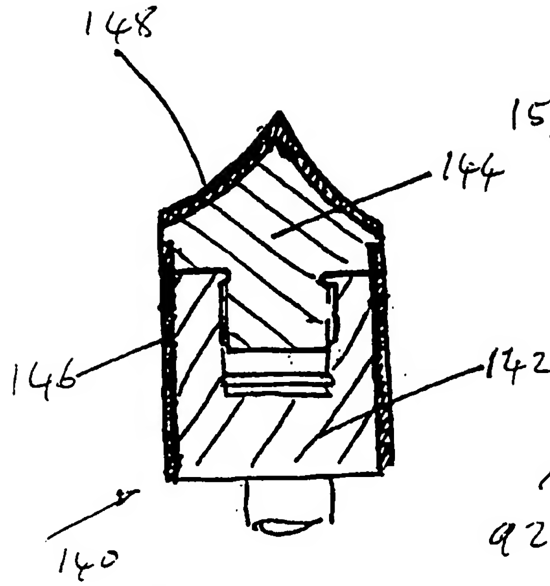


Fig 6

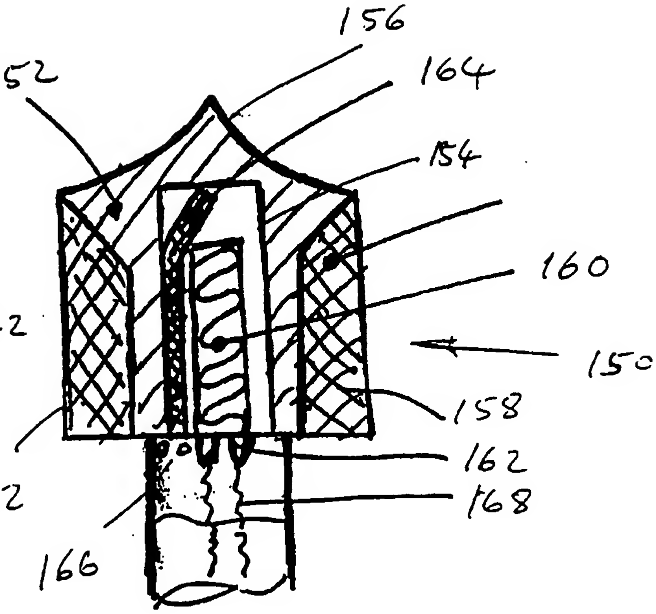


Fig 7

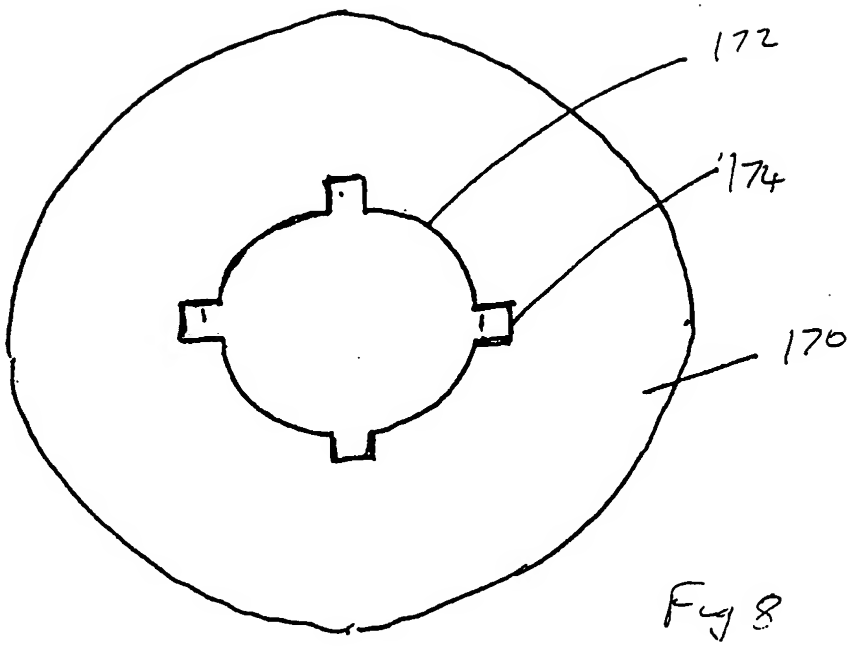


Fig 8

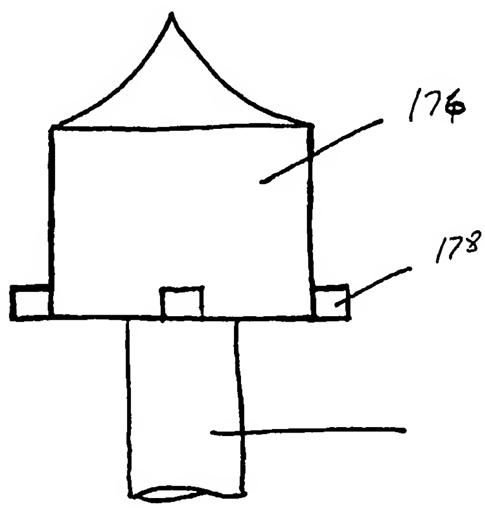


Fig 9a

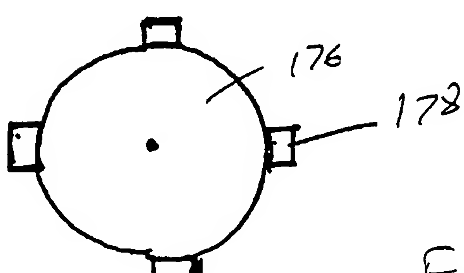


Fig 9b

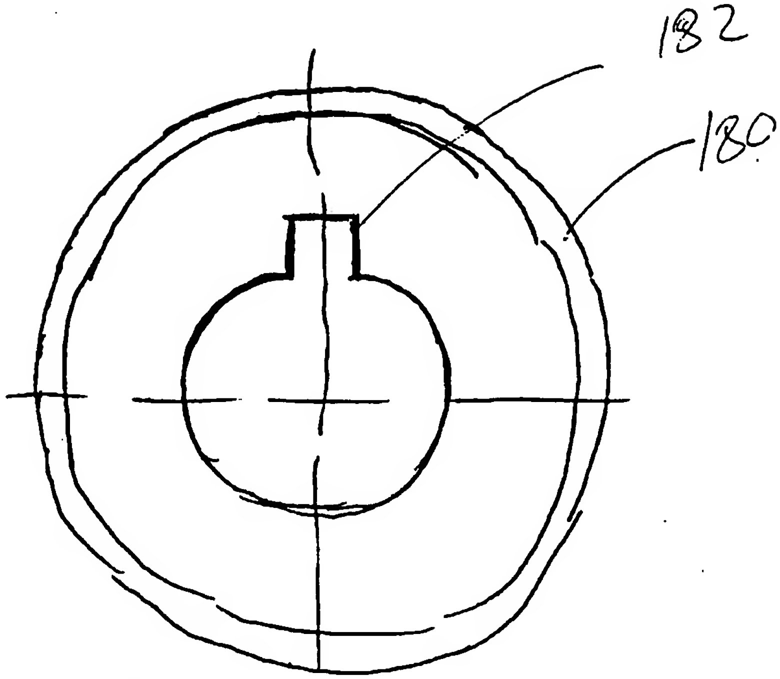


Fig 10

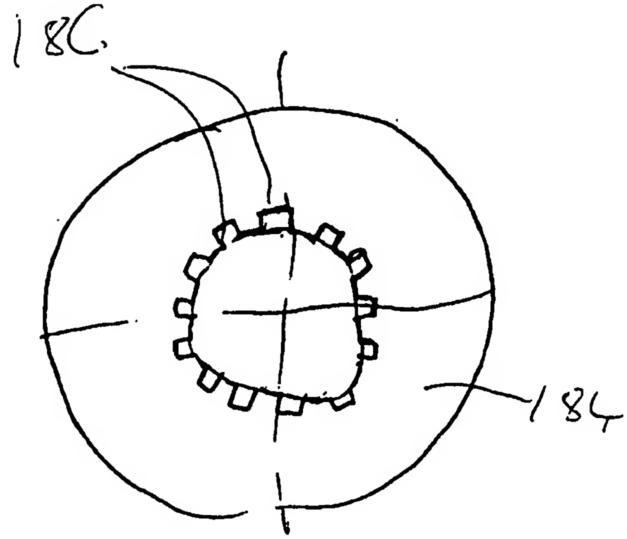
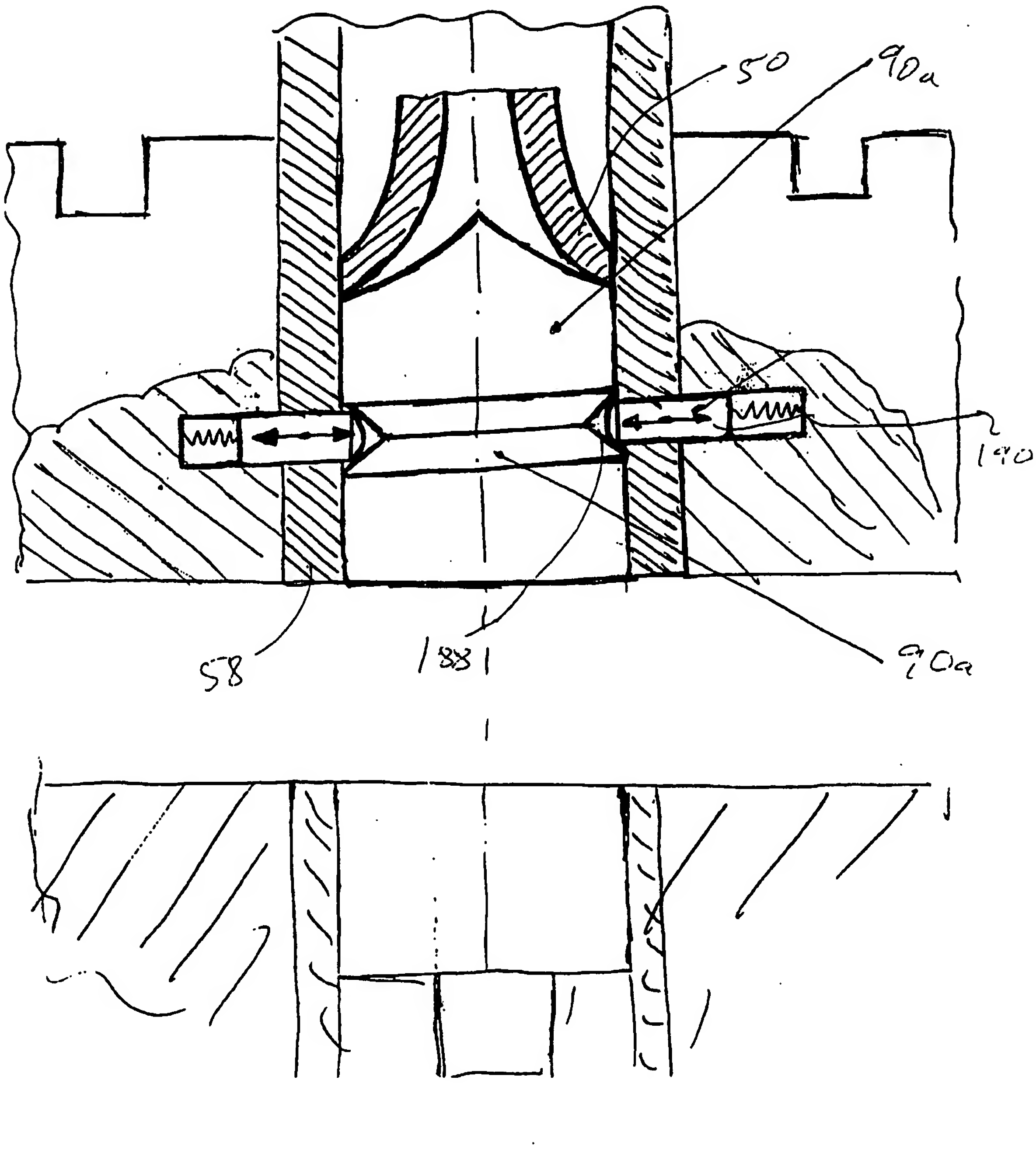


Fig 11

Fig 12



INTERNATIONAL SEARCH REPORT

Inte onal Application No
PCT/CA 97/00827

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B29C45/28

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B29C

Documentation searched other than minimumdocumentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 552 098 A (KUDO JUNICHIRO ET AL) 3 September 1996 cited in the application see column 14, line 16 - column 16, line 12; figures 14,15	1
A		2-45
A	EP 0 467 393 A (MEIKI SEISAKUSHO KK) 22 January 1992 see figures	1-45
A	WO 92 08597 A (GPT AXXICON BV) 29 May 1992 cited in the application see the whole document	1-45

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of theinternational search	Date of mailing of the international search report
10 February 1998	02/03/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Jensen, K

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INTERNATIONAL SEARCH REPORT

Internal onal Application No
PCT/CA 97/00827

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN vol. 007, no. 079 (M-204), 31 March 1983 & JP 58 005238 A (ASAHI KASEI KOGYO KK), 12 January 1983, see abstract ---	1,2,28, 35,41, 44,45
A	PATENT ABSTRACTS OF JAPAN vol. 007, no. 246 (M-253), 2 November 1983 & JP 58 132531 A (TATEISHI DENKI KK), 6 August 1983, see abstract ---	1,2,28, 35,41, 44,45
A	PATENT ABSTRACTS OF JAPAN vol. 008, no. 262 (M-341), 30 November 1984 & JP 59 133020 A (DAICEL KAGAKU KOGYO KK), 31 July 1984, see abstract ---	1,2,28, 35,41, 44,45
A	US 4 260 360 A (HOLMES JOHN R ET AL) 7 April 1981 see the whole document ---	
A	US 4 391 579 A (MORRISON ROCKY V) 5 July 1983 cited in the application see the whole document -----	

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Int .ional Application No
PCT/CA 97/00827

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5552098 A	03-09-96	JP 5096581 A	20-04-93
		JP 5185475 A	27-07-93
		JP 5293869 A	09-11-93
		AT 152662 T	15-05-97
		CN 1074170 A	14-07-93
		CN 1125655 A	03-07-96
		DE 69219550 D	12-06-97
		DE 69219550 T	04-09-97
		EP 0537953 A	21-04-93
		EP 0705676 A	10-04-96
		US 5326240 A	05-07-94
EP 0467393 A	22-01-92	JP 2683949 B	03-12-97
		JP 4078515 A	12-03-92
WO 9208597 A	29-05-92	JP 1988340 C	08-11-95
		JP 4176619 A	24-06-92
		JP 7010546 B	08-02-95
		AT 126473 T	15-09-95
		AU 655443 B	22-12-94
		AU 8918391 A	11-06-92
		DE 69112221 D	21-09-95
		DE 69112221 T	25-01-96
		EP 0556266 A	25-08-93
		ES 2075473 T	01-10-95
		HK 198296 A	08-11-96
		RU 2072918 C	10-02-97
		US 5324190 A	28-06-94
US 4260360 A	07-04-81	NONE	
US 4391579 A	05-07-83	AU 546766 B	19-09-85
		AU 7659181 A	31-03-83
		BR 8106963 A	10-05-83
		CA 1168408 A	05-06-84
		EP 0075043 A	30-03-83
		HK 48589 A	23-06-89
		JP 1298066 C	20-01-86
		JP 58057929 A	06-04-83
		JP 60023973 B	10-06-85